The Surprisingly Large Contribution of Small Marine Clouds to Cloud Fraction and Reflectance

Contributors

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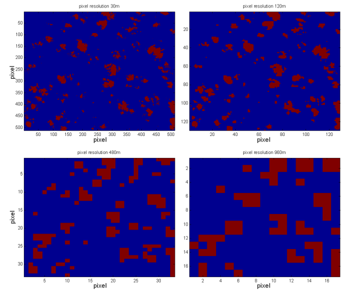
Research Highlight

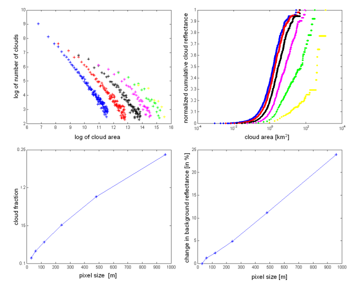
Clouds and aerosols are linked and have important roles in Earth's climate. Among other effects, they reflect and absorb solar radiation thus reducing the amount reaching the surface. Clouds wouldn't actually exist if a subset of aerosols called cloud condensation nuclei (CCN) was not available to provide a surface for water to condense or freeze on and to form cloud droplets and ice crystals. CCN availability therefore largely controls the number of cloud particles that are found in a developed cloud. One way to understand the collective and separate effects of clouds and aerosols on solar radiation is by observing them with satellite instruments. Being able, however, to detect with these instruments what is cloud and what is aerosol is not always easy, especially when searching for aerosol between clouds and when the clouds are small. Indeed, some shallow cumulus clouds have diameters as small as 10 meters and these, as well as some larger clouds, can be easily missed by 1 km resolution sensors like the moderate-resolution imaging spectroradiometer (MODIS) used for global observations. We often interpret elevated reflectances (compared to background) in pixels containing such clouds as coming from aerosol. Misidentifications of this type eventually yield underestimates of the contribution of clouds to reflected radiation and overestimates of the contribution of aerosol.

Our paper studies these effects for shallow cumulus cloud fields over the tropical oceans where they often cover large areas. We have at our disposal data from the enhanced thematic mapper plus (ETM+) radiometer aboard the Landsat-7 satellite, which has a resolution of 30 m. Because the ocean surface offers a good dark backdrop, at this resolution we can detect most, but still not all, of these clouds. We find some interesting results. For five fields of shallow marine cumulus clouds, sampled from different geographic locations, we find that the largest number of clouds corresponds to the smallest clouds we can detect with ETM+. Because these clouds are so numerous they also contribute the largest fraction of the total solar radiation reflected by the entire cloud field, even though each individual cloud's reflectance is rather small. Estimates of the apparent cloud contribution to total reflected radiation that MODIS would give, are half of those at the original resolution (because of dilution of clear skies in our larger pixels that are still however reflective enough to be classified as cloudy). In contrast, the reflectance that comes from apparent cloud-free areas at MODIS resolution appears 25% larger than it actually is (because of cloud contamination in larger pixels that are classified as cloudless).

The importance of the above errors due to instrument resolution artifacts are obvious. When the larger reflectance from apparent cloud-free areas is attributed to aerosol, we reach wrong conclusions about the direct radiative forcing of aerosol in the present climate. Our estimate of the 24-hour forcing error is -0.8±0.2 W/m2 per cloud field, or about 15% to 20% of the total global



Cloud mask for a sparse cumulus cloud field as inferred by using the same threshold at four different spatial resolutions. The upper-left panel is for the original Landsat resolution and the lower-right panel is for a MODIS-equivalent resolution. Note how the small clouds far from other clouds are "dissolved" into the background while small clouds, holes between clouds, and background pixels next to large cloud edges are all classified as clouds.



Resolution effects on the size distributions of a sparse cloud field near Tahiti. Clockwise from top left: log-log cloud size distributions for resolutions ranging from 30 m (blue) to 960 m (yellow); normalized cumulative cloud reflectance distributions; change in apparent clear sky reflectance with resolution; change in cloud fraction with resolution. Note in the top panels how the size and energy distributions shift toward larger clouds as the resolution decreases.

aerosol effect estimated from MODIS aerosol retrievals. While this may not seem significant if only local, the fact that shallow cumulus cloud fields cover ~ 15% of the global oceans, makes it so.

Reference(s)

Koren, I, L Oreopoulos, G Feingold, LA Remer, and O Altaratz. 2008. "How small is a small cloud?" Atmospheric Chemistry and Physics Journal, in press

Working Group(s)

Cloud Properties